Journal of Applied Engineering and Technological Science
Vol 7(1) 2025: 119-128

OPTIMIZATION OF CONVOLUTIONAL NEURAL NETWORK FOR CLASSIFICATION OF HYDROPONIC VEGETABLE CULTIVATION USING MACHINE LEARNING

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Received: 24 February 2025, Revised: 17 September 2025, Accepted: 07 October 2025
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ABSTRACT
In an effort to apply applied product innovation and support the improvement of hydroponic vegetable cultivation, it is based on several things. Among them are changes in the texture of the year, stems and vegetable quality. At this time the problems faced by hydroponic vegetable pickers, especially banyumas village youth organizations who have UMKM hydroponic vegetable cultivation. This situation will have an impact on problems and losses that result in a lack of yield and quality of harvested vegetables if not resolved quickly. The results of this study resulted in optimal accuracy performance in the classification of hydroponic vegetables with CNN, this study also successfully classified normal vegetables with vegetables affected by disease. This research produces accuracy in the first test 73% and the second test 92%.
Keywords : *Optimization, Convolutional Neural Network, Classification, Hydroponic Vegetables, Machine Learning*

1. Introduction

One of the human needs in life is vegetables. Consuming vegetables can provide benefits, one of which can reduce deaths from non-communicable diseases. The provision of vegetables to be consumed must pay attention to the amount, quality, safety, and affordability of the vegetables themselves in order to achieve food security (Elinur et al., 2024; Prasetyo et al., 2024). In 2023, Indonesia continued to experience an increase in the number of vegetable imports. The net weight of vegetable imports in 2019 was 770,378.2 kg, while in 2023 the amount of vegetable imports reached 1,000,490.2 kg ("Impor Sayuran Menurut Negara Asal Utama, 2018-2023.," 2019). This shows the great need of the community for various types of vegetables. Therefore, its management must be maximized, one of the actions that can be taken is by using hydroponic techniques.

In agriculture, hydroponics makes optimal use of resources and space to increase crop yields. In order for plants to grow, a hydroponic system is needed in channeling water containing nutrients rather than soil to grow plants. The advantages of this method include better crop yields, better urban farming and gardening, and water that is not absorbed by the plants can be recirculated so as not to waste water (Priya et al., 2023; Takeuchi, 2019; Waluyo et al., 2023). However, farmers who want to use hydroponic techniques should consider the high cost at the start of manufacturing and consider the following factors: sunlight, conductivity, temperature, pH, water level, and humidity during growth and development (Vuong et al., 2024).

Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Random Forest are some of the machine learning methods previously used to support the classification and prediction of agricultural yield quality. While these methods have shown quite good results, they have one limitation: they cannot automatically extract image features. Differences in color, texture, and shape in agricultural image-based classification are often very complex, making them difficult to handle with manual feature-based methods.

The part of artificial intelligence that focuses on system development is machine learning. Because of these capabilities, researchers are increasingly interested in machine learning (Alfred et al., 2021; Qu et al., 2021; Rashid et al., 2021). Machine learning has been widely used in various fields because it has great potential for each field. Agriculture is one of them, as it is very useful for increasing crop production rates and yields (Ambavane et al., 2024; Ang & Seng, 2021). Three prediction and analysis machine learning has several approaches, including supervised learning, unsupervised learning, and supervised learning (Halbouni et al., 2022). Some machine learning algorithms include Random Forest (RF), Support Vector Machine (SVM), and K-Nearest

Neighbors (KNN). KNN is a regression-based prediction and classification algorithm (Ali et al., 2023; Sulaiman et al., 2024).

In this study, Convolutional Neural Networks (CNNs) were chosen due to their superior ability to extract image features hierarchically and automatically without the need for complex feature engineering. CNNs have also proven effective in various image processing applications, such as identifying leaf diseases, plant classification, and determining fruit quality. Therefore, CNNs are more accurate than learning models.

This research hopes that the Convolutional Neural Network (CNN) method can extract good features in classifying the quality of hydroponic vegetables based on the shape of their leaf images. The purpose of this research is to determine the resulting classification process through evaluation of the accuracy, precision, and recall matrices of the CNN algorithm performance. CNN, a very deep field of learning that focuses on speech recognition and image classification, has attracted the attention of many scientists. Different convolutional artificial neural network (CNN) architectures have improved the ability to recognize and classify images. CNNs can function well when extracting hierarchical representations from image data. This happens when high-level features are built from a combination of low-level features (Mjahad et al., 2023; Mudgil et al., 2022).

In research conducted by Wongpatikaseree, et al. (Wongpatikaseree et al., 2018) Smart farming uses machine learning and image processing to distinguish between fresh and wilted vegetables in hydroponic farming. The researchers compared Naive Bayes decision tree, Multilayer Perceptron, and deep neural network types. The researchers hypothesized that neural networks would have good accuracy, but the results of this study show that decision trees have the best accuracy with an accuracy rate of 98.12%.

In research conducted by Fitriani, et al. (Fitriani et al., 2022) do hydroponic cultivation. The problem in this study is in the form of monitoring and controlling nutrition, As a result, researchers used the Hydroponic Nutrient Film Technique (NFT) to create an automatic control system of nutrients and pH. Microcontroller with CNN method is used as a control system process, in which the parameters of pH; pH drop; food; nutrition; water pump; also input the flame duration to achieve the researcher's target value. The study showed an error value of 3.35% for healthy control and 0.98% for pH control.

In research conducted by Sangeetha, et al. (Sangeetha & Periyathambi, 2024) in his study called “Automatic nutrient estimator: distributing nutrient solution to hydroponic plants based on plant growth”.This research aims to provide nutrient concentrations that have been adjusted to the needs of plants and in the hydroponic system is expected to minimize the resources used and can overcome other challenges when using hydroponic techniques. The author realizes the goal by presenting hydroponic nutrient estimator that can be integrated into hydroponic systems. Plants are grown with deep water culture, four peristaltic pumps controlled by Arduino papa sensors, and an identification algorithm to identify the plant stage. The results in this study showed the algorithm identified the growth stage with 97.5% accuracy and identified the vegetative state during the first 5 weeks with 1,715 ppm nutrition, flowering time was 97.5% during 6-9 weeks with 2,380 ppm nutrition, and fruiting position was 99.4% during the last 10-15 weeks with 2,730 ppm nutrition.

The aim of this study was to optimize CNN performance in classifying hydroponic vegetables using harvest images. This was done to improve the accuracy of quality detection and support the efficiency of contemporary agricultural production. In this study, researchers will identify the classification of hydroponic vegetables. The proposed model with convolutional neural network classification is able to classify hydroponic vegetables and is evaluated using accuracy, precision and recall.

2. Literature Review

This section reviews previous research on the topic of convolutional neural network method implementation. The findings of previous research will be explained first below.

The authors (Lumbantoruan et al., 2025) discuss convolutional neural network (CNN), which helps to reduce the number of classes. The results of the two-step classification method compare the proposed two-step CNN with the baseline CNN in terms of effectiveness and efficiency. Extensive experiments show that the two-step CNN outperforms the baseline, CNN, and jellyfish residue network (JF-ResNet), with an accuracy improvement of 4% and 99%, respectively.

Many image-based agricultural applications utilize Convolutional Neural Networks (CNNs). Through leaf analysis, soil type classification using hyperspectral data, and texture and morphology recognition of leaves and fruits, CNNs have proven effective in detecting plant diseases. CNNs can extract features automatically and hierarchically without relying on manual feature engineering, which is often less flexible to field conditions. This is a CNN advantage compared to traditional methods. Several studies have compared CNNs with other algorithms such as Support Vector Machine (SVM), K-Nearest Neighbor (KNN), and Random Forest. These traditional methods can still be used on small datasets with simple features, but their performance may decrease on more complex datasets.

However, object detection architectures like YOLO are better suited for situations involving multiple objects and real-time queries, such as finding damaged fruit or leaves in a field. Furthermore, recent research has demonstrated the importance of CNN optimization methods for improving accuracy and generalization. Techniques such as applying dropout as regularization, using data augmentation (such as rotation, flipping, and lighting adjustment), and tuning the learning rate with a dynamic scheduler have been shown to reduce overfitting and accelerate convergence. Agricultural image classification models can deliver more accurate and robust results to support the efficiency of contemporary agricultural production, including in hydroponic systems, with the right combination of CNN architecture and optimization techniques.

The authors (Alam et al., 2024) In the current review, a thorough research is given on hydroponics, which is an advanced technology used to produce vegetables. It discusses many things about hydroponics, such as the methods used, benefits and drawbacks, and its applications in vegetable production. In addition, the paper discusses the history of the development of hydroponics, the various systems, essential parts, and nutritional functions of nutrient solutions to promote plant growth. Moreover, the paper points out several agricultural advantages of hydroponic cultivation, including better crop yields, more efficient use of water, optimal space utilisation, and lack of environmental impact. In addition, hydroponic issues such as initial set-up costs, technicalities, complexity, and disease management are discussed in this review. In the study (Chen et al., 2024) In this study, we analysed various harmful chemicals, including 120 pesticides, 18 phthalates (PAEs), and 2 heavy metals (lead and cadmium) in four types of vegetables, grown hydroponically and conventionally in soil. The vegetables were tomato celery, cucumber and celery. Our study found that at least one pesticide was found in 84% of the conventionally grown samples, while only 30% of the hydroponic samples showed residual pesticides. There was no significant difference between hydroponic and conventional vegetables in terms of total PAE concentration. The hazard index (HI) value of hydroponic vegetables was 0.22, while that of conventional hydroponic vegetables was 0.64. As both values are less than one, the exposure of the studied vegetables to these hazardous chemicals may not pose a significant health hazard.

3. Research Methods

This method will provide a thorough explanation of the general application and actions taken to prepare data for this research model. Image data preparation begins when the data is collected and then processed by the model. This includes enlarging, enhancing, and processing the image data to make it better understood for subsequent use (Qisthi & Siswono, 2024).

3.1. Datasets

Existing data on hydroponic vegetables will be used in this study. (Lubis et al., 2024). The dataset used is classification data between hydroponic vegetable leaves taken from ECO Farm hydroponic farmers. With a total of 500 images of data which are divided into 2 classes, namely disease vegetable leaves and normal vegetable leaves. Where the amount of data used in the class of leaves with disease is 325 and normal leaves are 175 images.

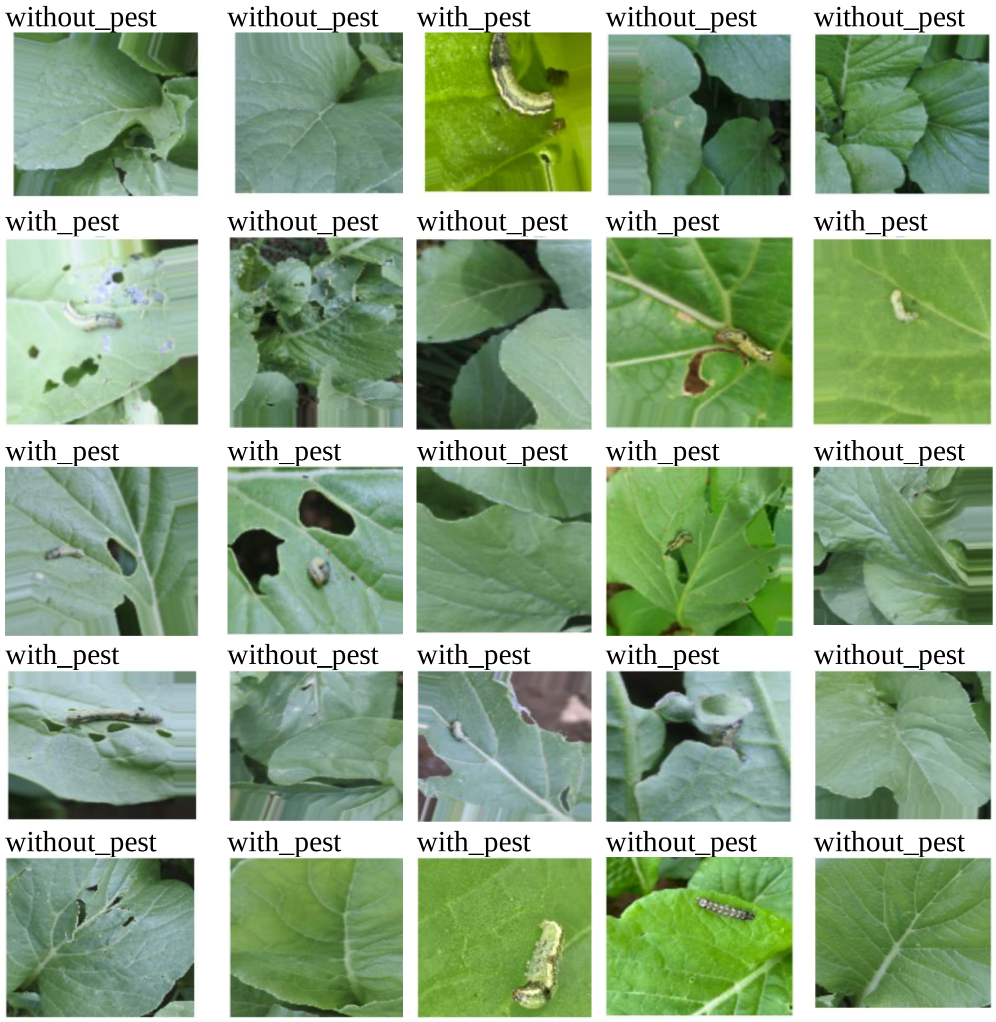

Fig. 1. Hydroponic vegetable dataset

3.2. Measurement and observation parameters

This research designs to build and analyze the **Average RGB Value (Red, Green, Blue):** Calculates the average red, green, and blue color values in plant images. **Color Histogram:** The distribution of color intensity in the image for each color channel**. Vegetation Index (NVDI):** An index that measures plant health based on reflected red and near infrared light (Syarief & Setiawan, 2020).

3.3. Framework

This stage discusses the flow of the implementation of the research model and the stages in the research carried out by applying the convolutional neural network algorithm. The following figure shows the stages of the research implementation.

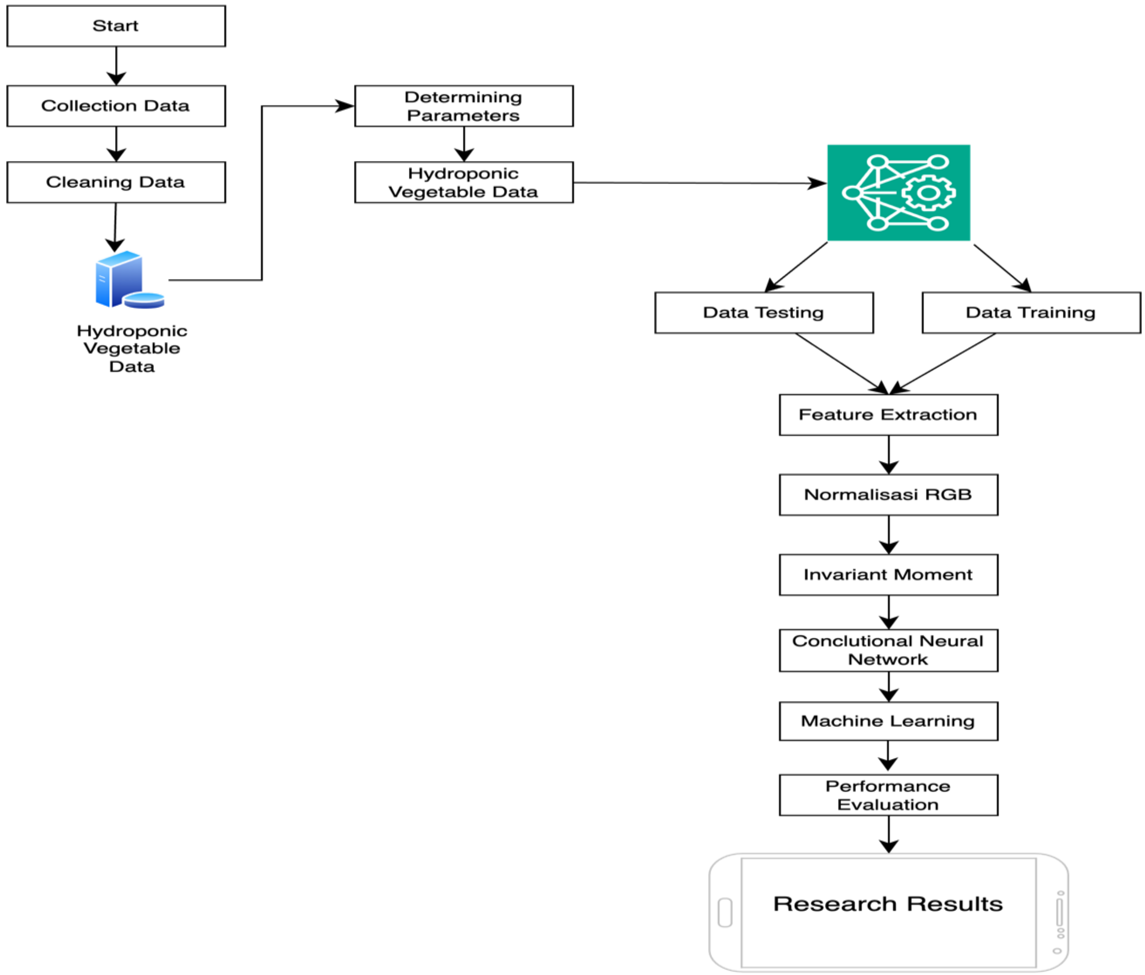

Fig. 2. Architecture of CNN solving method

3.4. Evaluation performance

To analyze a model, certain metrics are needed to determine how well the classification model is functioning. Calculating this measure can use a confusion matrix. (Ravi & Matt, 2024). Confusion matrix element analysis makes it possible to evaluate the performance of classification models. This study utilizes various metrics, including accuracy, precision, recall, and F1 score.

4. Results and Discussions

At this stage, the results of the research are discussed in this section where researchers conducted experiments to test with performance evaluation on a personal computer. The computer used was MAC Pro M1. The model implementation was done using python programming language in google coolab application. The researcher presents the results and discusses the findings of the research on the application of convolutional neural network classification to the hydroponic vegetable dataset. The performance metrics used to evaluate the proposed method are accuracy, precision, recall, and f1-score (Lanyak et al., 2024).

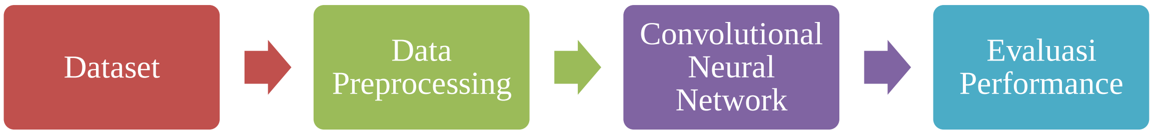

Fig. 3. Stages of the testing process

4.1. Dataset

In this study, researchers evaluated data from the results of photos on hydroponic farming at eco farm. The dataset used is classification data between hydroponic vegetable leaves taken from ECO Farm hydroponic farmers. With a total of 500 images of data which are divided into 2 classes, namely disease vegetable leaves and normal vegetable leaves. Where the amount of data used in the class of leaves with disease is 325 and normal leaves are 175 images shown in Figure 1.

4.2. Data preprocessing

After the training process, the researchers will perform the model performance evaluation stage with the implementation of test data to determine the ability of the convolutional neural network model to interact with the set of hydroponic vegetable images. The purpose of this check is to evaluate the accuracy, precision, and recall of the f1 score, as shown in the following figure.

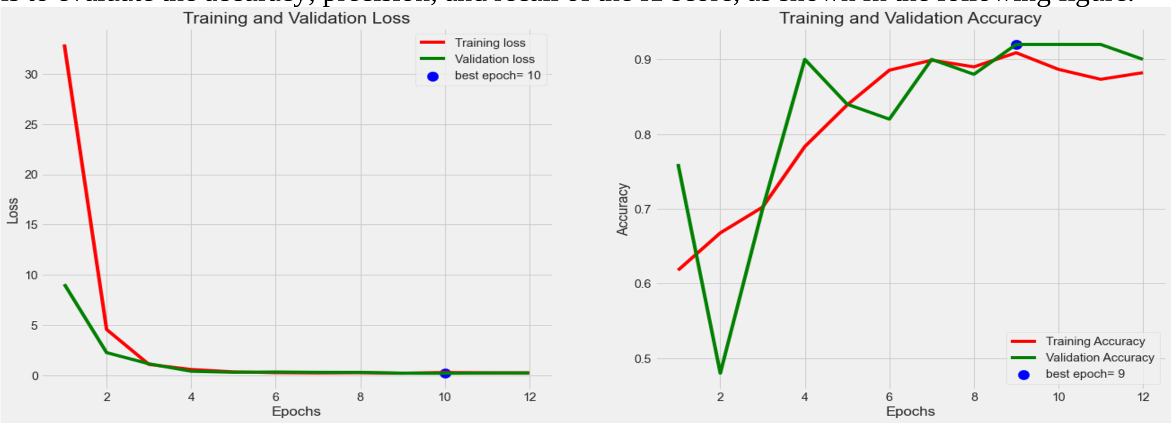

Fig. 4. First training and validation results

accuracy on the test set is 73.00 %

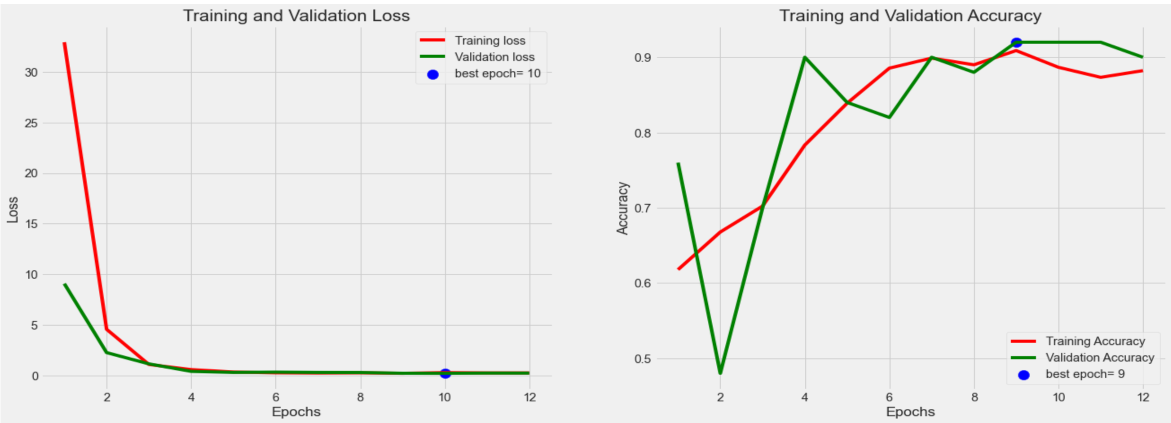

Fig. 5. Second training and validation results

accuracy on the test set is 92.00 %

Figures 4 and 5 show the accuracy results of several tests, where the accuracy of the first test is 73% while the second test with 92% accuracy. These test results show that the implemented model can perform the training and validation process of the hydroponic vegetable image dataset.

4.3. Visualisation results confusion matrix

The data visualization results show the results of using a model that uses a clutter matrix; the clutter matrix is a very useful tool for assessing the performance of a classification model. Using this matrix, we can see how the model predicts each class by comparing it to the actual labels. This allows us to find the errors made by the model. The test results show that the error value without_test is 1.0 and with_pest is 3.0.

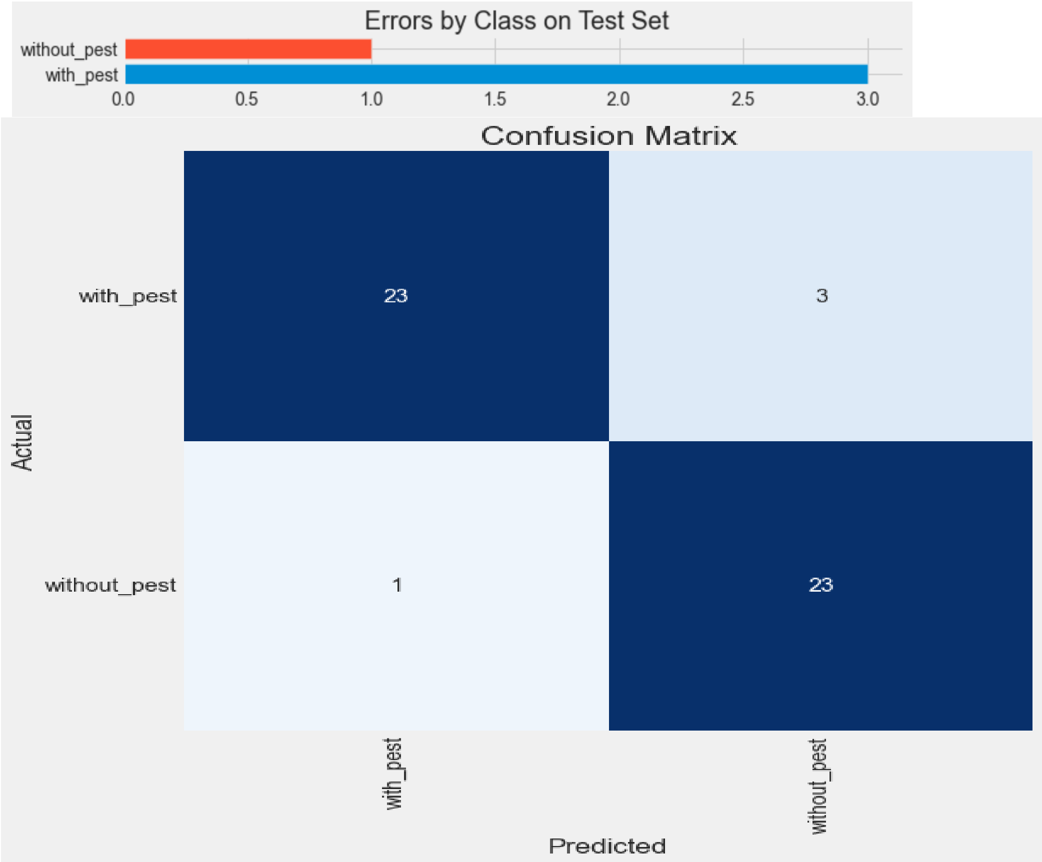

Fig. 6. Confusion results and prediction data

4.4. Deep learning evaluation

At this stage, the author conducts testing using the performance matrix evaluation. This stage will evaluate the model using The data was tested to determine the ability to apply the model. The purpose of this evaluation is to determine the results of the mode accuracy. This evaluation uses accuracy, accuracy, recall, f1 score, and support. Tables 1 and 2 show this.

Table 1 - Results of performance appraisal

Dataset: Green vegetable leaf image

	Precision	Recall	F1-Score	Support
With_pest	0.96	0.88	0.92	26
Without_pest	0.88	0.96	0.92	24
Accuracy			0.92	50
Macro Avg	0.92	0. 92	0. 92	50
Weighted Avg	0.92	0. 92	0. 92	50

Table 2 - Results of performance appraisal

Dataset: Green vegetable leaf image

	Precision	Recall	F1-Score	Support
With_pest	0.64	1.00	0.78	47
Without_pest	1.00	0.49	0.66	53
Accuracy			0.73	100
Macro Avg	0.82	0.75	0.72	100
Weighted Avg	0.83	0.73	0.71	100

5. Conclusion

This research hopes that the Convolutional Neural Network (CNN) method can extract good features in classifying the quality of hydroponic vegetables based on the shape of their leaf images. The purpose of this research is to determine the resulting classification process through evaluation of the accuracy, precision, and recall matrices of the CNN algorithm performance. The results of this study resulted in optimal accuracy performance in the classification of hydroponic vegetables with CNN, this study also successfully classified normal vegetables with vegetables affected by disease. This research produces accuracy in the first test of 73% and the second test of 92%.

Acknowledgement

In this research, the author does not forget to thank the DIPA funds of Medan State Polytechnic in 2024 with contract number: B/426/PL5/PT.01.05/2024, along with all parts that carry out this PTPI scheme research.

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